Nutrient cycle - linking the Atmosphere, Terrestrial, Marine and Glaciological flagship programmes in Ny-Ålesund

The project is a combined project (workshops and network)

Submitted by Norwegian Polar Institute

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Core project group consists of the 4 flagships chairs and co-chairs, as well as key contributors from the flagships working groups on various aspects of the nutrient cycle:
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Excellence

National and/or international collaboration

This proposal will increase cross-flagship collaboration by setting up meeting places to bring individual scientists working on the nutrient cycles within the marine, terrestrial, atmosphere and cryosphere domain together with a main goal of increasing collaboration between institutes and countries. Actors from all institutes active in Ny-Ålesund will be invited to take part in a series of cross-cutting activities to create synergies on already existing work, and make new networks and collaboration. The flagships have a good history in collaborating with actors at the other three research locations in Svalbard, and this will be brought along in this new proposal.

Addressing the same topic from various angles will bring together researchers and research methods from different disciplines, institutions and nations, thereby increasing collaboration, expanding networks and ultimately create better science. Different experimental approaches are considered, for their complementarity, to be more successful than single approaches. Bringing together people that work on nutrient aspects in the Arctic regions, will give the opportunity to interpret the results in a more comprehensive and complete perspective. The activities will continue after the project period as part of the Ny-Ålesund flagship programmes.

Objectives

Overall goal of the project is to understand perturbations in nutrient cycles in the Artic linked to ongoing environmental change. Nutrient cycling involves all compartments of the ecosystem and thus bringing all four Ny-Ålesund flagship programs together is a natural step to address this research subject. We plan to start the work with overview of current knowledge, gaps and together develop hypothesis and research questions we can address with join forces of all four flagship programs. We aim at high-end scientific peer-reviewed publication based on relevant field measurements, modelling and remote sensing data done by scientists from different disciplines from many institutions and countries with data from several locations in Svalbard.

This approach and common scientific goals will strengthen cross-flagship collaboration and networking in Ny-Ålesund, making the research community in Ny-Ålesund even stronger together.

To understand changes in **one** ecosystem or sphere one cannot exclude to study the relationship with the other spheres. This is valid in particular in Arctic regions where the changes, as well as effects of changes, are so drastic. At a joint flagship meeting in Oslo in November 2019, the flagship chairs and co-chairs were challenged to identify a common topic to link the flagships' disciplines. Nutrients is a critical link between the atmosphere, biosphere and cryosphere, and were chosen as the first theme in order to increase the multidisciplinary research and cross-flagship activities in Ny-Ålesund.

Ny-Ålesund and its surrounding area provide a unique study site to document and understand ongoing changes and to predict future Arctic ecosystem trajectories. The long research background across multiple systems (atmosphere, glaciers, tundra ecosystems) and multidisciplinary knowledge on Kongsfjorden and adjacent marine systems is a great strength and resource that is available nowhere else in the Arctic. It is important and increasingly urgent to use this knowledge to give foundation to robust and reliable predictions.
However, the coupling of atmosphere, land and sea has been somewhat overlooked in the research conducted in Ny-Ålesund and Kongsfjorden. The same may be said about research conducted elsewhere in Svalbard. Therefore, the work proposed herein will focus on these interactions using Kongsfjorden as a harbinger of the future Arctic.

This project will bring together all Ny-Ålesund flagships in an attempt to evaluate nutrient fluxes between Kongsfjorden and its surrounding environment - terrestrial, glacier, atmospheric and ocean realms - and how some of these fluxes are expected to change with the ongoing warming trends. It will contribute to understand how Net Ecosystem Metabolism (NEM) will change and how this may impact the coastal zone. It will provide an opportunity to expand the geographical range of application of the Land Ocean Interactions in the Coastal Zone (LOICZ) approach. This will prove useful in the near future in helping to understand some of the ecosystem shifts expected from Atlantification of Arctic fjords. Net Ecosystem Metabolism is one of the holistic ecosystem properties that informs more about ecosystem functioning. Its calculation implies the calculation of the water budget, the salt budget and, finally, the nitrogen budget. Moreover, nitrogen NEM links stoichiometrically to the phosphorus, oxygen and carbon budgets, allowing to get insight into the carbon sink/source role of a given ecosystem. Changes in NEM lead to changes in the interactions with neighbouring ecosystems and may be indicators of changes in ecosystem health. Considering the theory of ecological succession, one may assume as a starting point that changes corresponding to an ecosystem shift from a higher succession stage to a lower one, will be followed by a deviation of NEM further away from zero and this may be seen as a decrease in ecosystem health, since it corresponds to a decrease in ecosystem "self-sustainability".

Our understanding on the effects of increased CO_2, temperature and UV radiation on Arctic marine primary producers is mainly restricted to the summer months. During this time, continuous solar irradiation coincides with a nutrient-depleted and strongly stratified environment. Due to the combination of these factors, Arctic algae in summer are prone to regular or even chronic photoinhibition, that only disappears as the darkness progressively increases towards the autumn. However, increasing global temperature may lead to the release of different forms of inorganic nitrogen (N) and phosphorus (P), mainly from terrestrial sources. We hypothesize that increased contribution to the N and P pools in the fjord in summer may affect growth and metabolic performances of phytoplankton as well as benthic micro- and macrophytes. Conclusive data on the effects of N and P enrichment in summer on growth and physiological performance of other macrophytes, associated benthic microalgae, and pelagic phytoplankton are, particularly in this area, not available. Given the strong interactive effects of nutrient limitation and other environmental drivers (e.g. temperature, CO_2, light availability) on the competition between photosynthetic organisms, such knowledge is indispensable when assessing the potential for climate change adaptation of the Kongsfjorden ecosystem.

There is a wealth of data and knowledge about Kongsfjorden, as shown in a recent publication (Hop, H., Wiencke, C.W. (eds.), 2019. The ecosystem of Kongsfjorden, Svalbard. Advances in Polar Biology). Considering that this ecosystem may be seen as a harbinger of change, such knowledge is of utmost importance to understand what will be the future trends elsewhere in Arctic coastal systems. However, it is still lacking the effort of bringing some of the available information into ecosystem level measures of state. This may be achieved only by integrating data across disciplines. Glacial and terrestrial systems provide several seasonal inputs to Arctic fjords through glacier and river discharges. The melting of permafrost and the retreat of tidewater glaciers onto land will likely change the magnitude and the water quality of these discharges. This will have implications on the water and nutrient budgets, possibly impacting, in a global sense, the so-called “ecosystem metabolism”. Moreover, the retreat onto land of tidewater glaciers will have implications in fjord circulation and primary production.

Freshwater inputs to the fjord are crucial for understanding fjord circulation and the fjord ecosystem. There are two sources of freshwater to the fjord system: rain and snow or ice melt. A number of glaciers have been studied extensively in the Ny-Ålesund area, mostly with respect to mass balance and hydrology. Recently, the flow of glacial meltwater to glacier fronts has been modelled, in Kongsfjord and around Svalbard, providing freshwater flux data for use in fjord circulation modeling and for elucidating fjord ecosystem dynamics.

At terrestrial level, carbon and nutrient fluxes are studied in relationship to global warming, in particular, carbon fluxes are measured as emissions at ecosystem, plant and soil level and as sequestration by the vegetation and by the ocean. In this perspective, the results obtained at the terrestrial level can be directly related with the measurements at atmospheric and at marine level and be used as components of the Carbon cycle. Arctic soils are generally poor in nutrients (N and P), the concentrations measured in Ny-Ålesund indicate, indeed, strong N- and P-limitation. Despite this limitation, supply of nutrients to soil can occur mainly from animal faeces, birds and herbivores, and from the increase of plant primary production associated to global warming via litter decomposition. Nutrient contribution to soils may be beneficial for further increase vegetation primary productivity and at the same time, contribute to increase nutrient content in superficial water reaching the sea. Evaluate and distinguish the different sources of nutrient into land water and how this may have effects on nutrients in sea is an important issue to deal with. In particular, in relationship to the effects the increasing air temperature may have on plant primary production and litter decomposition, but also on the increase of nutrients availability, as a consequence of soil warming and permafrost thawing.

Atmospheric deposition is the most dynamic and variable nutrient input pathway. We will evaluate deposition pathways and fluxes of major (N, P,S, C) as well as minor components (Base cations, trace, metals) from point of view of temporal variability and anthropogenic versus natural contribution. Trends in climatic parameters and meteorology will help to understand changes in nutrients distribution and exchange between various compartments.

Cross-cutting topics to investigate further include:

1. To evaluate nutrient exchanges for the pelagic and the benthic compartment. Top down approach: we could begin by trying to implement the LOICZ (Land Ocean Interactions Along the Coastal Zone) method and get an estimate of Net Ecosystem Metabolism in N units. Then we would know better if Kongsfjorden acts as a sink or source of N to the nearby coastal waters.
2. Sources of nutrients and spatial differences in Kongsfjorden (rivers, WSC, glaciers, airborne transport, recycling in the water column and in the benthos).
3. The role of nutrient supply from terrestrial sources during the summer and autumn for primary production and to better understand the trade-off between higher nutrients and greater turbidity (with associated light limitation).

4. Consumption of nutrients by phytoplankton and phytobenthos. Relation to productivity of macro and microalgae.
5. Phytoplankton blooms.
6. Competition of phytoplankton and macroalgae for the nutrients. Role of increased temperature in the dynamics of both compartments in a nutrient-enriched fjord. Seasonal study of phytoplankton and benthos dynamics in a changing environment, with increased nutrient supply and increased temperature.
7. Do kelps themselves re-supply part of the nutrients they need from their constant deterioration, meaning is there a gradient in nutrient concentration from within the kelp forest to the open water?
8. Snowmelt dynamics of NO3- release. What consequences might this release pattern have on ecosystems within and below the snow?
9. What consequences will the deposition regimes, post-depositional alterations and snowmelt patterns have on the preservation of NO3- in the glacier ice and thus he interpretation of ice core records from this region as approximations for past contributions of nutrients to the ecosystem?
10. Work towards developing robust transfer functions that integrate atmospheric, terrestrial and aquatic nutrient reservoirs.
11. Past and present marine biogenic productivity integrating the glacier ice archive record with present observations

This proposal fulfils all SSF strategic objectives. This project is based on close **coordination** and **cooperation** between all Ny-Ålesund flagships and between scientists based in Svalbard and elsewhere in order to gather, organize and analyse data collected by researchers working in different fields and bring it into a coherent whole. By doing so it will also promote the **open sharing of data** between institutions as a necessary condition to achieve the proposed goals. The project is based on the analysis of the available data. Therefore, it will have a **reduced environmental impact** since it will not imply new field or laboratory research activities. It will promote the **planning of international research in Svalbard** because in seeking the project goals many questions will be raised that will lead to the elaboration of an international project proposal.

Impact

Added value of the network project or workshop

The proposal is directly connected to the four Ny-Ålesund flagship programmes, and hence previous and current SSG projects related to these. The two SSG projects “The Terrestrial Ecology Flagship in Ny-Ålesund: reinforcement and further development - activities for 2018-2019” and “Ny-Ålesund Atmosphere Flagship Program: Further development and strengthening of the collaboration” both end this year, and to secure future activities for the Atmosphere flagships a new SSG grant proposal is planned. The SSG project “Kongsfjorden System Flagship Programme Creating a network for further enhancement of marine related research and monitoring in Ny-Ålesund” have funding throughout 2020.

Longterm- and process- oriented measurements from Kongsfjorden and around, together with the proposed setup offer excellent opportunities to produce peer-review publication of high scientific impact. By expanding the Ny-Ålesund work to other parts of Svalbard and beyond, findings and results from Ny-Ålesund are brought to the international pan-Arctic community.

The Kongsfjorden flagship working group 4 *Seasonal control of nutrient regime* has programmed a common review paper in which all groups involved in the study of photoautotrophs will participate. Winter campaigns as well as laboratory simulations using both micro and macroalgae have provided interesting new data about the ecophysiology of these organisms during polar night and their relation to nutrient blooms. The Terrestrial Ecology Flagship is preparing a review paper of the numerous research activities developed in Ny-Ålesund, and the fluxes of nutrients among the different components of the terrestrial

ecosystems are one focus point, in particular for the flagship work group 4 dedicated to *Carbon and Nutrient Fluxes*.

Relevance and benefit to society

The results of this collaborative project might help to design management plans for the Arctic zone. This project is going to address, in part, a problem that directly affect all coastal zones of the world, from which the Arctic is not going to escape: Eutrophication. This directly affects the whole coastal ecosystem, from microalgae (both planktonic and benthic) to macroalgae, zooplankton, as well as to higher trophic levels. This may introduce significant changes in the ecology of the coastal regions of the Arctic.

Environmental impact

Two dedicated workshops are planned to take place as side meetings to PNW and SSC to take advantage of the existing meeting places and to minimize additional travel. One of the writing workshops in spring 2021 could potentially take place in Ny-Ålesund or Longyearbyen in a period of the year when possibly several participants are already at Svalbard for experimental campaigns. The increased collaboration between groups to coordinate activities and field work also reduce the environmental footprint of the researchers to the pristine environment studied.

Implementation

Project activities

1 March 2020: Project start and online kick off meeting for core project group.
Fall 2020: Open workshop on the nutrient cycle - linking the atmosphere, marine, terrestrial and cryosphere domains. 3 days workshop, appr. 25 scientists, to be arranged by CNR in Rome. The workshop will include a few keynote presentations on the nutrients cycle, including working groups on different aspects of the nutrient issues. Workshop output: sketch up for several per-review publications.
January 2021 (during SIOS Polar Night Week): First writing meeting. Output: first draft manuscript (-s)
Spring 2021 (TBD, take advantage of other relevant meeting places): Core writing group workshop (-s)
Nov 2021 (Svalbard Science Conference): Finalizing writing group workshop (-s)
Nov 2021 (Svalbard Science Conference): Propose a dedicated session on nutrient cycle for SSC 2021. Present results (oral and posters) from common work and publications at the conference.
January 2022: Final online meeting with core project group. Plan next steps.
Feb 2022: Project end

Resources, expertise, distribution of roles and cooperation

The project group for this joint flagship proposal consists of the eight flagship chairs and co-chairs. The project leader is the NySMAC secretariat from Norwegian Polar Institute (Christina Pedersen), which have been involved in the flagships since 2013, and have contributed to coordinate the activities. Each of the flagships have working groups with WG leaders (constituting the scientific committees of the flagships) which can be activated when/if needed. Both the Marine and Terrestrial flagships have relevant workgroups focusing on various aspects of nutrients, which will be important when designing the first workshop, and later; the writing group meeting. The flagships themselves maintain webpages and email-list, and these foras will be used to distribute information about the open activities within this proposal.